

## Electricity and Magnetism, Spain

CEM (Centro Español de Metrología), LCOE (Laboratorio Central Oficial de Electrotecnica), TPYCEA (Taller de Precision y Central Electrotécnico de Artilleria)

| Calibration or Measurement Services                      |   |  | Measurand Level or Range |               |       | Measurement Conditions/Independent variables |                    | Expanded Uncertainty |       |                 |                     |   |                    |   |     |                        |
|--|---|--|--------------------------|---------------|-------|--|--------------------|----------------------|-------|-----------------|---------------------|---|--------------------|---|-----|------------------------|
| Quantity   | Instrument or artifact                      | Instrument Type or Method  | Minimum value            | Maximum value | units | Parameter                                    | Specifications     | Value                | Units | Coverage Factor | Level of Confidence | Is the expanded uncertainty a relative one? | Uncertainty matrix | Comments                                | NMI | NMI Service Identifier |
| DC voltage sources: single values                        | Standard cell, solid state voltage standard | Series opposition  | 1                        | 10            | V     | Voltage                                      | 1 V, 1.018 V, 10 V | 50                   | nV/V  | 2               | 95%                 | Yes   |                    |   | CEM | 1                      |
| DC voltage sources: low values                           | DC voltage source                           | Comparison to a voltage standard and a resistive divider by 1 V step | 1                        | 10            | V     |  |                    | 1                    | µV/V  | 2               | 95%                 | Yes   |                    |   | CEM | 2                      |
| DC voltage sources: intermediate values                  | DC voltage source                           | Comparison to a voltage standard and a resistive divider             | 10                       | 1000          | V     |  |                    | 1                    | µV/V  | 2               | 95%                 | Yes   |                    |   | CEM | 3                      |
| DC voltage sources: low values                           | DC voltage source                           | Comparison to a voltage standard and a resistive divider             | 0.1                      | 1000          | mV    |  |                    | 20 to 1000           | nV    | 2               | 95%                 | No  |                    |   | CEM | 4                      |
| DC voltage meters: very low values                       | Nanovoltmeter, microvoltmeter               | Comparison to a voltage standard and a resistive divider             | 0.1                      | 1             | mV    |  |                    | 20                   | nV    | 2               | 95%                 | No  |                    |   | CEM | 6a                     |
| DC voltage meters: intermediate values                   | Nanovoltmeter, microvoltmeter               | Comparison to a voltage standard and a resistive divider             | 0.1                      | 1000          | mV    |  |                    | 20 to 1000           | nV    | 2               | 95%                 | No  |                    |   | CEM | 6b                     |
| DC voltage meters: intermediate values                   | Voltmeter, multimeter                       | Comparison to a voltage standard and a resistive divider             | 1                        | 1000          | V     |  |                    | 1                    | µV/V  | 2               | 95%                 | Yes   |                    | Linearity, voltmeters from 7 1/2 digits | CEM | 7                      |
| DC voltage ratios up to 1100 V                           | Resistive divider                           | Comparison to a reference divider                                    | 0.01                     | 0.1           |       | Maximum input voltage                        | 1100 V             | 0.85E-06             |       | 2               | 95%                 | Yes   |                    |   | CEM | 8                      |
| DC resistance standards and sources: low values          | Fixed resistor                              | DCC bridge and range extender  | 1                        | 100           | mΩ    | Temperature                                  | 20 °C to 25 °C     | 2                    | µΩ/Ω  | 2               | 95%                 | Yes   |                    | Oil and air baths                       | CEM | 9                      |
| DC resistance standards and sources: intermediate values | Fixed resistor                              | Josephson potentiometer  | 10                       | 10            | kΩ    | Temperature                                  | 20 °C to 25 °C     | 40                   | nΩ/Ω  | 2               | 95%                 | Yes   |                    | Oil and air baths                       | CEM | 10                     |

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|--|------------------------------------|---|--------------------------|---------------|-------|--|----------------|----------------------|-------|-----------------|---------------------|---|--------------------|-------------------|-----|------------------------|
| Quantity   | Instrument or artifact             | Instrument Type or Method                                 | Minimum value            | Maximum value | units | Parameter                                    | Specifications | Value                | Units | Coverage Factor | Level of Confidence | Is the expanded uncertainty a relative one? | Uncertainty matrix | Comments          | NMI | NMI Service Identifier |
| DC resistance standards and sources: intermediate values | Fixed resistor                     | Potentiometric  | 10                       | 10            | kΩ    | Temperature                                  | 20 °C to 25 °C | 70                   | nΩ/Ω  | 2               | 95%                 | Yes   |                    | Oil and air baths | CEM | 11                     |
| DC resistance standards and sources: low values          | Fixed resistor                     | DCC bridge by substitution and Hamon transfer             | 1                        | 1             | Ω     | Temperature                                  | 20 °C to 25 °C | 0.1                  | μΩ/Ω  | 2               | 95%                 | Yes   |                    | Oil and air baths | CEM | 12                     |
| DC resistance standards and sources: intermediate values | Fixed resistor                     | DCC bridge by substitution and Hamon transfer             | 100                      | 100           | Ω     | Temperature                                  | 20 °C to 25 °C | 80                   | nΩ/Ω  | 2               | 95%                 | Yes   |                    | Oil and air baths | CEM | 13                     |
| DC resistance standards and sources: intermediate values | Fixed resistor                     | DCC bridge by substitution                                | 1                        | 10000         | Ω     | Temperature                                  | 20 °C to 25 °C | 0.2                  | μΩ/Ω  | 2               | 95%                 | Yes   |                    | Oil and air baths | CEM | 14                     |
| DC resistance standards and sources: intermediate values | Fixed resistor                     | High resistance bridge by substitution                    | 10                       | 100           | kΩ    | Temperature                                  | 20 °C to 25 °C | 1                    | μΩ/Ω  | 2               | 95%                 | Yes   |                    | Oil and air baths | CEM | 15                     |
| DC resistance standards and sources: intermediate values | Fixed resistor                     | High resistance bridge by substitution and Hamon transfer | 0.1                      | 1             | MΩ    | Temperature                                  | 20 °C to 25 °C | 2                    | μΩ/Ω  | 2               | 95%                 | Yes   |                    | Oil and air baths | CEM | 16                     |
| DC resistance standards and sources: high values         | Fixed resistor                     | High resistance bridge by substitution and Hamon transfer | 1                        | 10            | MΩ    | Temperature                                  | 20 °C to 25 °C | 3                    | μΩ/Ω  | 2               | 95%                 | Yes   |                    | Oil and air baths | CEM | 17                     |
| DC resistance standards and sources: high values         | Fixed resistor                     | High resistance bridge by substitution and Hamon transfer | 10                       | 100           | MΩ    | Temperature                                  | 20 °C to 25 °C | 4                    | μΩ/Ω  | 2               | 95%                 | Yes   |                    | Oil and air baths | CEM | 18                     |
| Capacitance: low loss capacitors                         | Standard capacitors (fused silica) | Transformer bridge by substitution                        | 10                       | 100           | pF    | Frequency                                    | 1 kHz          | 3                    | μF/F  | 2               | 95%                 | Yes   |                    |                   | CEM | 19                     |

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| Calibration or Measurement Services                                 |  |                                    | Measurand Level or Range |               |       | Measurement Conditions/Independent variables |                  | Expanded Uncertainty |          |                 |                     |   |                          |  |     |                        |
|---|--|------------------------------------|--------------------------|---------------|-------|--|------------------|----------------------|----------|-----------------|---------------------|---|--------------------------|--|-----|------------------------|
| Quantity  | Instrument or artifact                     | Instrument Type or Method          | Minimum value            | Maximum value | units | Parameter                                    | Specifications   | Value                | Units    | Coverage Factor | Level of Confidence | Is the expanded uncertainty a relative one? | Uncertainty matrix       | Comments                                     | NMI | NMI Service Identifier |
| Capacitance: low loss capacitors                                    | Standard capacitors (dry nitrogen)         | Transformer bridge by substitution | 10                       | 1000          | pF    | Frequency                                    | 1 kHz            | 6                    | µF/F     | 2               | 95%                 | Yes   |                          |  | CEM | 20                     |
| Capacitance: dielectric capacitors                                  | Standard capacitors (mica)                 | Direct comparison                  | 1                        | 1000          | nF    | Frequency                                    | 1 kHz            | 100                  | µF/F     | 2               | 95%                 | Yes   |                          |  | CEM | 21                     |
| AC voltage: AC-DC transfer difference at low voltages               | AC/DC transfer standard, thermal converter | Comparison                         | 0.1                      | 0.5           | V     | Frequency                                    | 10 Hz to 1 MHz   | 30 to 405            | µV/V     | 2               | 95%                 | Yes   | <a href="#">Unc-tab1</a> |  | CEM | 22                     |
| AC voltage: AC-DC transfer difference at medium voltages            | AC/DC transfer standard, thermal converter | Comparison                         | 0.5                      | 5             | V     | Frequency                                    | 10 Hz to 1 MHz   | 4 to 50              | µV/V     | 2               | 95%                 | Yes   | <a href="#">Unc-tab1</a> |  | CEM | 23                     |
| AC voltage: AC-DC transfer difference at higher voltages            | AC/DC transfer standard, thermal converter | Comparison and step up procedure   | 5                        | 1000          | V     | Frequency                                    | 10 Hz to 1 MHz   | 8 to 100             | µV/V     | 2               | 95%                 | Yes   | <a href="#">Unc-tab1</a> |  | CEM | 24                     |
| AC voltage up to 1000 V: sources                                    | Multifunction calibrator                   | AC/DC transfer                     | 0.1                      | 1000          | V     | Frequency                                    | 10 Hz to 1 MHz   | 20 to 450            | µV/V     | 2               | 95%                 | Yes   | <a href="#">Unc-tab2</a> |  | CEM | 35                     |
| AC voltage up to 1000 V: meters                                     | AC voltmeter, multimeter                   | AC/DC transfer                     | 0.1                      | 1000          | V     | Frequency                                    | 10 Hz to 1 MHz   | 20 to 450            | µV/V     | 2               | 95%                 | Yes   | <a href="#">Unc-tab2</a> | Voltmeters and multimeters from 6 1/2 digits | CEM | 41                     |
| AC current: AC-DC transfer difference                               | Thermal current converter                  | Comparison and step up procedure   | 0.01                     | 20            | A     | Frequency                                    | 10 Hz to 100 kHz | 15 to 110            | µA/A     | 2               | 95%                 | Yes   | <a href="#">Unc-tab3</a> |  | CEM | 47                     |
| AC power and energy: single phase ( $f \leq 400$ Hz), active power  | Power converter, power meter               | Comparison and step up procedure   | 600                      | 600           | W     | Voltage                                      | 120 V            | 50                   | µW/VA    | 2               | 95%                 | Yes   |                          |  | CEM | 52                     |
|   |  |                                    |                          |               |       | Current                                      | 5 A              |                      |          |                 |                     |   |                          |  |     |                        |
|   |  |                                    |                          |               |       | Frequency                                    | 45 Hz to 55 Hz   |                      |          |                 |                     |   |                          |  |     |                        |
|   |  |                                    |                          |               |       | Power factor                                 | 1                |                      |          |                 |                     |   |                          |  |     |                        |
| AC power and energy: single phase ( $f \leq 400$ Hz), active energy | Energy meter                               | Comparison and step up procedure   | 16.66                    | 16.66         | Wh    | Voltage                                      | 120 V            | 50                   | µWh/VA h | 2               | 95%                 | Yes   |                          |  | CEM | 53                     |

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| Calibration or Measurement Services                                  |                        |                           | Measurand Level or Range |               |       | Measurement Conditions/Independent variables |                                    | Expanded Uncertainty |                           |                 |                     |   |                    |   |     |                        |
|--|------------------------|---------------------------|--------------------------|---------------|-------|--|------------------------------------|----------------------|---------------------------|-----------------|---------------------|---|--------------------|---|-----|------------------------|
| Quantity   | Instrument or artifact | Instrument Type or Method | Minimum value            | Maximum value | units | Parameter                                    | Specifications                     | Value                | Units                     | Coverage Factor | Level of Confidence | Is the expanded uncertainty a relative one? | Uncertainty matrix | Comments  | NMI | NMI Service Identifier |
|  |                        |                           |                          |               |       | Current                                      | 5 A                                |                      |                           |                 |                     |   |                    |   |     |                        |
|  |                        |                           |                          |               |       | Frequency                                    | 45 Hz to 55 Hz                     |                      |                           |                 |                     |   |                    |   |     |                        |
|  |                        |                           |                          |               |       | Power factor                                 | 1                                  |                      |                           |                 |                     |   |                    |   |     |                        |
|  |                        |                           |                          |               |       | Measuring time                               | 100 s                              |                      |                           |                 |                     |   |                    |   |     |                        |
| AC power and energy: single phase ( $f \leq 400$ Hz), active power   | Power meter            | Direct comparison         | 0.006                    | 24            | kW    | Voltage                                      | 60 V to 480 V                      | 100                  | $\mu\text{W}/\text{VA}$   | 2               | 95%                 | Yes   |                    | Minimum value of uncertainty with a power factor equal to 1 | CEM | 54                     |
|  |                        |                           |                          |               |       | Current                                      | 0.2 A to 50 A                      |                      |                           |                 |                     |   |                    |   |     |                        |
|  |                        |                           |                          |               |       | Frequency                                    | 45 Hz to 55 Hz                     |                      |                           |                 |                     |   |                    |   |     |                        |
|  |                        |                           |                          |               |       | Power factor                                 | 1 to 0.5, inductive or capacitive  |                      |                           |                 |                     |   |                    |   |     |                        |
| AC power and energy: single phase ( $f \leq 400$ Hz), active energy  | Energy meter           | Direct comparison         | 0.166                    | 666.6         | Wh    | Voltage                                      | 60 V to 480 V                      | 100                  | $\mu\text{Wh}/\text{VA}$  | 2               | 95%                 | Yes   |                    | Minimum value of uncertainty with a power factor equal to 1 | CEM | 55                     |
|  |                        |                           |                          |               |       | Current                                      | 0.2 A to 50 A                      |                      |                           |                 |                     |   |                    |   |     |                        |
|  |                        |                           |                          |               |       | Frequency                                    | 45 Hz to 55 Hz                     |                      |                           |                 |                     |   |                    |   |     |                        |
|  |                        |                           |                          |               |       | Power factor                                 | 1 to 0.5, inductive or capacitive  |                      |                           |                 |                     |   |                    |   |     |                        |
|  |                        |                           |                          |               |       | Measuring time                               | 100 s                              |                      |                           |                 |                     |   |                    |   |     |                        |
| AC power and energy: single phase ( $f \leq 400$ Hz), reactive power | Power meter            | Direct comparison         | 0.003                    | 24            | kvar  | Voltage                                      | 60 V to 480 V                      | 200                  | $\mu\text{var}/\text{VA}$ | 2               | 95%                 | Yes   |                    |   | CEM | 56                     |
|  |                        |                           |                          |               |       | Current                                      | 0.2 A to 50 A                      |                      |                           |                 |                     |   |                    |   |     |                        |
|  |                        |                           |                          |               |       | Frequency                                    | 45 Hz to 55 Hz                     |                      |                           |                 |                     |   |                    |   |     |                        |
|  |                        |                           |                          |               |       | $\sin\phi$                                   | 1 to 0.25, inductive or capacitive |                      |                           |                 |                     |   |                    |   |     |                        |

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| Calibration or Measurement Services                                   |  |                                   | Measurand Level or Range |               |       | Measurement Conditions/Independent variables |                                    | Expanded Uncertainty |                              |                 |                     |   |                    |  |      |                        |
|---|--|-----------------------------------|--------------------------|---------------|-------|--|------------------------------------|----------------------|------------------------------|-----------------|---------------------|---|--------------------|--|------|------------------------|
| Quantity  | Instrument or artifact   | Instrument Type or Method         | Minimum value            | Maximum value | units | Parameter                                    | Specifications                     | Value                | Units                        | Coverage Factor | Level of Confidence | Is the expanded uncertainty a relative one? | Uncertainty matrix | Comments                                       | NMI  | NMI Service Identifier |
| AC power and energy: single phase ( $f \leq 400$ Hz), reactive energy | Energy meter   | Direct comparison                 | 0.083                    | 666.6         | varh  | Voltage                                      | 60 V to 480 V                      | 200                  | $\mu\text{varh}/\text{V Ah}$ | 2               | 95%                 | Yes   |                    |  | CEM  | 57                     |
|   |  |                                   |                          |               |       | Current                                      | 0.2 A to 50 A                      |                      |                              |                 |                     |   |                    |  |      |                        |
|   |  |                                   |                          |               |       | Frequency                                    | 45 Hz to 55 Hz                     |                      |                              |                 |                     |   |                    |  |      |                        |
|   |  |                                   |                          |               |       | $\sin\phi$                                   | 1 to 0.25, inductive or capacitive |                      |                              |                 |                     |   |                    |  |      |                        |
|   |  |                                   |                          |               |       | Measuring time                               | 100 s                              |                      |                              |                 |                     |   |                    |  |      |                        |
| High DC voltage: high voltage sources                                 | High DC voltage sources  | Comparison with reference system  | 1                        | 200           | kV    |  |                                    | 200                  | mV/kV                        | 2               | 95%                 | Yes   |                    |  | LCOE | 59                     |
| High DC voltage: high voltage meters                                  | Measuring system for high DC voltage                               | Comparison with reference system  | 1                        | 200           | kV    |  |                                    | 200                  | mV/kV                        | 2               | 95%                 | Yes   |                    |  | LCOE | 60                     |
| High DC voltage: ratios   | DC high voltage dividers, DC high voltage probes                   | Comparison with reference divider | 1E-06                    | 1             |       | Voltage                                      | 1 kV to 200 kV                     | 200                  | 1E-06                        | 2               | 95%                 | Yes   |                    |  | LCOE | 61                     |
| AC high voltage: sources  | High voltage AC source   | Comparison with reference system  | 1                        | 200           | kV    | Frequency                                    | 50 Hz, 60 Hz                       | 500                  | mV/kV                        | 2               | 95%                 | Yes   |                    |  | LCOE | 62                     |
| AC high voltage: meters, rms values                                   | AC high voltage measuring system                                   | Comparison with reference system  | 1                        | 200           | kV    | Frequency                                    | 50 Hz, 60 Hz                       | 500                  | mV/kV                        | 2               | 95%                 | Yes   |                    |  | LCOE | 63                     |
| AC high voltage: peak values  | AC measuring system  | Comparison with reference system  | 1                        | 200           | kV    | Frequency                                    | 50 Hz, 60 Hz                       | 500                  | mV/kV                        | 2               | 95%                 | Yes   |                    |  | LCOE | 64                     |
| AC high voltage: ratio error  | High voltage transformer, high voltage divider                     | Bridge                            | 0                        | 2E-02         |       | Primary / secondary voltage                  | 1 kV to 200 kV / 100 V to 110 V    | 200E-06              |                              | 2               | 95%                 | No  |                    | <i>This CMC is related to the next one</i>     | LCOE | 65                     |
| AC high voltage: ratio: phase displacement                            | High voltage transformer, high voltage divider: phase displacement | Bridge                            | 1E-06                    | 2             | crad  | Primary / secondary voltage                  | 1 kV to 200 kV / 100 V to 110 V    | 0.02                 | crad                         | 2               | 95%                 | No  |                    | <i>This CMC is related to the previous one</i> | LCOE | 66                     |

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| Calibration or Measurement Services                                   |  |   | Measurand Level or Range |               |       | Measurement Conditions/Independent variables |  | Expanded Uncertainty |       |                 |                     |   |                                 |  |        |                        |
|---|--|---|--------------------------|---------------|-------|--|--|----------------------|-------|-----------------|---------------------|---|---------------------------------|--|--------|------------------------|
| Quantity  | Instrument or artifact   | Instrument Type or Method                               | Minimum value            | Maximum value | units | Parameter                                    | Specifications                           | Value                | Units | Coverage Factor | Level of Confidence | Is the expanded uncertainty a relative one? | Uncertainty matrix              | Comments   | NMI    | NMI Service Identifier |
| Pulsed high voltage and current: lightning impulse voltage parameters | High voltage divider, high voltage measuring system, EMC surge generator: peak values        | Comparison with high voltage reference measuring system | 1                        | 600           | kV    | Impulse shape                                | according to IEC 60060-1                 | 5                    | mV/V  | 2               | 95%                 | Yes   |                                 | According to IEC 60060-2<br>This CMC is related to the next one          | LCOE   | 67                     |
| Pulsed high voltage and current: lightning impulse time parameters    | High voltage divider, high voltage measuring system, EMC surge generator: front time         | Comparison with high voltage reference measuring system | 0.84                     | 1.56          | μs    | Impulse shape                                | according to IEC 60060-1; 1 kV to 600 kV | 20                   | 1E-03 | 2               | 95%                 | Yes   |                                 | According to IEC 60060-2<br>This CMC is related to the next one          | LCOE   | 68                     |
| Pulsed high voltage and current: lightning impulse time parameters    | High voltage divider, high voltage measuring system, EMC surge generator: time to half value | Comparison with high voltage reference measuring system | 40                       | 60            | μs    | Impulse shape                                | according to IEC 60060-1; 1 kV to 600 kV | 10                   | 1E-03 | 2               | 95%                 | Yes   |                                 | According to IEC 60060-2<br>This CMC is related to the two previous ones | LCOE   | 69                     |
| Pulsed high voltage and current: switching impulse voltage parameters | High voltage divider, high voltage measuring system, EMC surge generator: peak value         | Comparison with high voltage reference measuring system | 1                        | 1000          | kV    | Impulse shape                                | according to IEC 60060-1                 | 1                    | mV/V  | 2               | 95%                 | Yes   |                                 | According to IEC 60060-2   | LCOE   | 70                     |
| Scalar RF attenuation: on coaxials                                    | Passive device   | WBCO attenuator parallel IF substitution                | 0                        | 90            | dB    | Frequency                                    | 10 MHz to 40 GHz                         | 0.01 to 0.47         | dB    | 2               | 95%                 | No  | <a href="#">TPYCEA_Unc-tab5</a> |  | TPYCEA | 71                     |
| RF voltage: RF-DC transfer difference                                 | Thermal voltage converter  | Comparison  | 0.5                      | 4             | V     | Frequency                                    | 1 MHz to 50 MHz                          | 30 to 1500           | μV/V  | 2               | 95%                 | Yes   | <a href="#">Unc-tab4</a>        |  | CEM    | 58                     |

**Electricity and Magnetism, Spain, CEM (Centro Español de Metrología)****Uncertainty table: Unc-tab1**

AC voltage: AC-DC transfer difference at low voltages, CEM Internal Identifier: 22

AC voltage: AC-DC transfer difference at medium voltages, CEM Internal Identifier: 23

AC voltage: AC-DC transfer difference at higher voltages, CEM Internal Identifier: 24

|                        | <b>10 Hz</b> | <b>20 Hz</b> | <b>40 Hz to 100 Hz</b> | <b>1 kHz to 10 kHz</b> | <b>20 kHz</b> | <b>50 kHz</b> | <b>100 kHz</b> | <b>300 kHz to 500 kHz</b> | <b>700 kHz to 1 MHz</b> |
|------------------------|--------------|--------------|------------------------|------------------------|---------------|---------------|----------------|---------------------------|-------------------------|
| <b>100 mV / 200 mV</b> | 70           | 55           | 55                     | 55                     | 55            | 65            | 65             | 155                       | 405                     |
| <b>600 mV</b>          | 50           | 30           | 30                     | 30                     | 30            | 30            | 30             | 75                        | 130                     |
| <b>1 V / 2 V</b>       | 8            | 6            | 4                      | 4                      | 4             | 4             | 8              | 20                        | 45                      |
| <b>3 V</b>             | 5            | 4            | 4                      | 4                      | 4             | 4             | 5              | 20                        | 45                      |
| <b>5 V</b>             | 8            | 6            | 7                      | 7                      | 7             | 7             | 7              | 22                        | 50                      |
| <b>10 V</b>            | 15           | 10           | 8                      | 8                      | 8             | 8             | 10             | 26                        | 50                      |
| <b>20 V</b>            | 20           | 12           | 10                     | 10                     | 10            | 10            | 14             | 30                        | 50                      |
| <b>30 V</b>            | 30           | 18           | 15                     | 15                     | 15            | 15            | 15             | -                         | -                       |
| <b>50 V</b>            | 30           | 22           | 20                     | 20                     | 20            | 20            | 20             | -                         | -                       |
| <b>100 V</b>           | 30           | 22           | 20                     | 20                     | 20            | 20            | 24             | -                         | -                       |
| <b>200 V</b>           | 40           | 25           | 23                     | 20                     | 20            | 23            | 39             | -                         | -                       |
| <b>300 V</b>           | 60           | 40           | 40                     | 30                     | 30            | 25            | 50             | -                         | -                       |
| <b>500 V</b>           | 60           | 50           | 50                     | 40                     | 40            | 40            | 60             | -                         | -                       |
| <b>1000 V</b>          | 70           | 53           | 42                     | 40                     | 50            | 66            | 100            | -                         | -                       |

The expanded uncertainties given in this table are expressed in  $\mu\text{V/V}$

**Electricity and Magnetism, Spain, CEM (Centro Español de Metrología)**
**Uncertainty table: Unc-tab2**

AC voltage up to 1000 V: sources, CEM Internal Identifier: 35

AC voltage up to 1000 V: meters, CEM Internal Identifier: 41

|                        | <b>10 Hz</b> | <b>20 Hz to 10 kHz</b> | <b>20 kHz</b> | <b>50 kHz</b> | <b>100 kHz</b> | <b>200 kHz to 500 kHz</b> | <b>1 MHz</b> |
|------------------------|--------------|------------------------|---------------|---------------|----------------|---------------------------|--------------|
| <b>100 mV / 200 mV</b> | 120          | 80                     | 80            | 80            | 80             | 170                       | 450          |
| <b>0.5 V / 1 V</b>     | 80           | 45                     | 45            | 45            | 45             | 160                       | 400          |
| <b>2 V / 10 V</b>      | 20           | 20                     | 20            | 20            | 20             | 160                       | 350          |
| <b>20 V</b>            | 22           | 20                     | 20            | 20            | 20             | 150                       | 300          |
| <b>60 V / 200 V</b>    | 40           | 30                     | 30            | 35            | 60             | -                         | -            |
| <b>600 V / 1000 V</b>  | 65           | 60                     | 70            | 90            | 150            | -                         | -            |

The expanded uncertainties given in this table are expressed in  $\mu\text{V/V}$

**Uncertainty table: Unc-tab3**

AC current: AC-DC transfer difference, CEM Internal Identifier: 47

|                         | 10 Hz | 20 Hz | 40 Hz to 10 kHz | 20 kHz | 50 kHz | 100 kHz |
|-------------------------|-------|-------|-----------------|--------|--------|---------|
| <b>10 mA</b>            | 20    | 15    | 15              | 15     | 40     | 50      |
| <b>20 mA / 100 mA</b>   | 40    | 30    | 30              | 30     | 50     | 70      |
| <b>200 mA / 1000 mA</b> | 80    | 60    | 60              | 60     | 80     | 100     |
| <b>2 A / 10 A</b>       | 100   | 90    | 90              | -      | -      | -       |
| <b>20 A</b>             | 110   | 100   | 100             | -      | -      | -       |

The expanded uncertainties given in this table are expressed in  $\mu\text{A}/\text{A}$

**Uncertainty table: Unc-tab4**

RF voltage: RF-DC transfer difference, CEM Internal Identifier: 58

|                    | 1 MHz | 10 MHz | 30 MHz | 50 MHz |
|--------------------|-------|--------|--------|--------|
| <b>0.5 V / 1 V</b> | 100   | 200    | 600    | 1500   |
| <b>2 V / 3 V</b>   | 30    | 80     | 270    | 820    |
| <b>4 V</b>         | 40    | 100    | 300    | 1000   |

The expanded uncertainties given in this table are expressed in  $\mu\text{V/V}$

**Uncertainty table: TPYCEA\_Unc-tab5**

Scalar RF attenuation: on coaxials, TPYCEA Internal Identifier: 71

|              | <b>30 MHz</b> | <b>10 MHz to 12.4 GHz</b> | <b>12.4 GHz to 18 GHz</b> | <b>18 GHz to 26.5 GHz</b> | <b>26.5 GHz to 40 GHz</b> |
|--------------|---------------|---------------------------|---------------------------|---------------------------|---------------------------|
| <b>0 dB</b>  | 0.01          | 0.04                      | 0.05                      | 0.04                      | 0.07                      |
| <b>10 dB</b> | 0.02          | 0.05                      | 0.06                      | 0.08                      | 0.12                      |
| <b>20 dB</b> | 0.02          | 0.06                      | 0.07                      | 0.12                      | 0.17                      |
| <b>30 dB</b> | 0.02          | 0.08                      | 0.08                      | 0.16                      | 0.22                      |
| <b>40 dB</b> | 0.02          | 0.09                      | 0.09                      | 0.20                      | 0.27                      |
| <b>50 dB</b> | 0.02          | 0.10                      | 0.10                      | 0.24                      | 0.32                      |
| <b>60 dB</b> | 0.02          | 0.11                      | 0.11                      | 0.28                      | 0.37                      |
| <b>70 dB</b> | 0.07          | 0.15                      | 0.15                      | 0.32                      | 0.42                      |
| <b>80 dB</b> | 0.13          | 0.19                      | 0.19                      | 0.36                      | 0.47                      |
| <b>90 dB</b> | 0.18          | 0.22                      | 0.22                      | -                         | -                         |

The expanded uncertainties given in this table are expressed in dB